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Factors Contributing to Performance on Phoneme Awareness Tasks in School-aged Children*

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To examine factors potentially responsible for the robust association between phoneme awareness and reading ability, a novel pair of tasks was designed a) to control for nonlinguistic task variables and metacognitive skill; b) to minimize demands on working memory and verbal production; and c) to assess the role of reading experience and spelling strategies. With these factors taken into account, phoneme awareness remained significantly and specifically associated with decoding ability in children aged 71/2 to 10 years. Results on the new measure also corresponded to performance on an existing, widely used, measure of phonological awareness. In contrast, scores on the task selected as a closely parallel nonverbal analogue was unrelated to reading or to phonological awareness. These results, including comparisons of good and poor readers matched on reading level, but differing in age, suggest that the ability to isolate and identify phonemes continues to be an important determinant of reading aptitude during the school years.

Two decades of research has placed phonological awareness, and specifically phoneme awareness, squarely at the center of our efforts to understand the sources of reading disability. Children who have difficulty in reading also have difficulty in analyzing spoken language into the phoneme units to which letters roughly refer, or in performing operations upon these elements. Performance on phoneme analysis tasks involving phoneme counting, deletion, reversal or substitution has been shown to account for as much as 40 to 70% of the variance between skilled and unskilled readers (e.g., Mann, 1984; Mann & Liberman, 1984; Pratt & Brady, 1988; Rosner & Simon, 1971; Stanovich, Cunningham, & Feeman, 1984; Tunmer & Nesdale, 1985). However, recent research studies and the complex structure of phoneme awareness tasks leave some ambiguity about the locus of difficulty. Although training studies suggest that gaining access to the segmental nature of speech is important in first learning to read (e.g., Ball & Blachman, 1988; Bradley & Bryant, 1983; Lundberg, Frost & Peterson, 1988), a number of other factors common to phoneme awareness tasks and reading may contribute to the strong and continued association once reading instruction has begun.

In disentangling some of the many factors contributing to poor performance on phoneme awareness tasks, three areas merit close attention. First, it has been suggested that failure on phoneme awareness tasks may stem from a more general difficulty at the *metacognitive* level (e.g., Tunmer, 1988) that should be evident in nonlinguistic tasks as well. Second, it has been noted that those phoneme awareness tasks that correlate most strongly with reading beyond Grade 2 make heavy demands on the phonological

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processor, often requiring the child to hold a phonological string in *working memory*, to manipulate this string, and to produce a verbal response. It may be argued that these demands extend well beyond the simple awareness of the segmental structure of speech, making it difficult to determine whether poor performance stems from a lack of awareness or from difficulties with more basic aspects of phonological processing (Brady, in press; Yopp, 1988). Third, and perhaps most significantly, it has been argued that successful performance on phoneme awareness tasks may result from rather than predict success in acquiring written language. Many tasks taken as evidence of the child's access to phonology could involve *spelling strategies*, in which the child counts or manipulates letters rather than sounds. If spelling knowledge could lead to a correct response, then it is difficult to rule out the possibility that spelling leads and shapes the representations being tapped in phonological awareness tasks, rather than vice versa (Ehri, 1989; Morais, Cary, Alegria, & Bertelson 1979; Treiman, 1985).

In the present study, each of these concerns was given full consideration. To tease apart the contribution of each factor to poor performance on phoneme awareness measures, a need was recognized for a new, more analytic measure, with a parallel nonverbal control. When the variables discussed above have been taken into account, does awareness of the phonemic structure of words continue to be significantly and specifically associated with reading ability in school-aged children? Before describing the present study, designed to address this question, the concerns about each variable will be more fully discussed.

Metacognitive factors in phonological awareness. The original hypothesis generating an interest in phonological awareness focussed on the unnatural demands of reading (Gleitman & Rozin, 1977; Liberman, 1971; Rozin, 1975). Reading, in contrast to speaking or listening, requires the learner to become consciously aware of abstract phonological units embedded in a perceptually continuous speech stream. Although phoneme units may be available implicitly to guide the universal, early, and untutored development of speaking and listening, explicit awareness is available only to the cognitively mature child and then usually only in the context of direct instruction (Liberman, 1989). One hypothesis about the achievement of phoneme awareness is that it should be associated with metacognitive awareness in other tasks.

Such a possibility seems plausible when one considers the rather formidable cognitive requirements which characterize individual phonological awareness tasks. Almost any phonological awareness measure requires the child to isolate, identify, count, and order the abstract elements of the language. In more complex measures strongly associated with reading, children have been asked to select which of three choices does *not* match a target item in regard to the final segment (e.g., Bradley & Bryant, 1983); or to relate colored blocks to abstract phonological elements and to track transpositions of phonemic segments with exchanges of the appropriate blocks (Lindamood & Lindamood, 1971).

A small number of studies have directly addressed the possibility that the difficulty in performing metalinguistic tasks may derive from a more general failure to understand and cope with the nonlinguistic task requirements. Cognitive factors that have been investigated include following instructions, counting, sequencing, and isolating smaller units. As a visual analog to typical phonological awareness tasks, Lundberg (1978; Lundberg, Olofsson, & Wall, 1980) asked children to locate simple shapes within more complex meaningful pictures. Similarly, Mann (1986) asked children to count angles in a picture just as they counted phoneme segments. As auditory controls, Pratt and Brady (1988) and Morais, Bertelson, Cary, and Alegria (1986) developed xylophone tapping tasks to parallel some of the requirements of a phoneme segmentation test (Lindamood & Lindamood, 1971) and a phoneme deletion test (Rosner & Simon, 1971), respectively. The finding that none of these roughly comparable nonlinguistic measures is associated with reading minimizes the likelihood that the extraneous task demands assessed are critical factors in accounting for reading group differences in these studies.

On the other hand, several investigators have suggested that children must attain a minimum level in general cognitive development in order to be able to reflect upon and manipulate the structural features of language. In particular, it has been argued that phoneme awareness requires the ability to handle part-whole relations and to shift attention from meaning to form (i.e., to decenter); these achievements characterize the Piagetian stage of concrete operations (onset at 5 to 7 years). The most compelling evidence in support of this position derives from a prediction study in which children who lacked these general metacognitive abilities in kindergarten were unlikely to achieve phoneme awareness when reading instruction was introduced during the next year (see Tunmer Tunmer, Herriman, & Nesdale, 1988, for a review).

Similarly, Treiman and Baron (1981) suggested that an insensitivity to the internal structure of syllables (i.e., to phonemes) may be related to a general cognitive disposition of young children to focus on global rather than analytic aspects of stimuli (Smith & Kemler, 1977). However, in a direct test of this hypothesis, Mann, Tobin and Wilson (1988) compared kindergarten children's classification of nonsense syllables with their classification of geometric figures; in each case, a global and an analytic choice was available. They interpreted their failure to find a correlation between these two measures as arguing against the view that a common factor underlies the shift from a holistic to an analytic strategy.

To summarize, the evidence that general cognitive factors contribute importantly to performance on phoneme awareness tasks is suggestive, but limited. Because each new phoneme awareness measure introduces its own requirements, the present goal was to include an appropriate control task to assess and control for the contribution of general metacognitive skill to performance on both phoneme awareness and reading.

The role of working memory in phonological awareness tasks. Seeking to better understand the source of metaphonological problems in poor readers, a number of researchers have focussed their attention on more basic language processes in these individuals. There is growing evidence that the phonological structures underlying all of language processing are less well-developed in the poor reader (Liberman & Shankweiler, 1985; Stanovich, 1982). Among the abilities investigated, the most striking and pervasive characteristic of the poor reader is a difficulty in maintaining verbal material in memory; efficient operation of working memory appears to depend on strengths within the phonological domain (for reviews, see Brady, 1986; Jorm, 1983; and Torgesen, 1985). The poor reader is also less able to decode speech in noise (Brady, Shankweiler, & Mann, 1983; Palley, 1986), to accurately articulate tongue twisters and multisyllabic words (Rapala & Brady, 1990), or to access the phonological representation of words in the lexicon (Katz, 1986; Wolf & Goodglass, 1986). Although it remains to be determined whether one single deficit underlies all of these difficulties, and what effect reading experience has on these tasks, there is no question that in at least some poor readers, the phonological difficulties extend beyond awareness (Brady, 1986; Wagner & Torgesen, 1987).

In light of these more extensive phonological deficits, it is somewhat problematic that those phonological awareness tasks which correlate most strongly with reading beyond Grade 2 require considerable phoneme manipulation and therefore a heavy memory component (see Yopp, 1988). Such tasks also frequently involve lexical access and production of a verbal response as well. For example, the Auditory Analysis Test (AAT, Rosner & Simon, 1971), which is a strong predictor of reading success from kindergarten to adulthood, requires the child to apply all of these skills. In the AAT (e.g., "can you say smile without the /s/"), the child must repeat an incoming word, hold it in memory, isolate and remove the designated element, and reconstruct and accurately produce the new phonological sequence (also a word) without this segment (see Yopp, 1988, for a discussion). While a confounding of these factors may approximate the actual demands of reading, they obscure understanding how the various phonological deficits of reading are related to each other (Wagner & Torgesen, 1987).

Evidence that stressing working memory may mask the true abilities of children with reading disability derives from work on syntax. Although poor readers often lag behind good readers when asked to complete ungrammatical sentences, to explain ambiguities, or to detect, correct, or explain semantically and/or syntactically anomalous sentences (e.g., Bowey, 1986; Ryan & Ledger, 1984; Siegel & Ryan, 1984), it has been proposed that poor these limitations may derive from inadequate phonological processing (Crain & Shankweiler, 1988; Shankweiler & Crain, 1986). According to this view, although knowledge of syntactic structures may be intact, limitations in phonological processing constrict the operation of working memory, leading to poor performance on sentence-level tasks.

In a direct test of this possibility, Fowler (1988) asked children in regular classes to make judgments of grammaticality and to correct violations of grammaticality on the same set of sentences; memory and syntactic factors were systematically manipulated. Each task was metacognitive inasmuch as it required children to focus on form rather than content (Galambos & Hakuta, 1988; Gleitman, Gleitman, & Shipley, 1972), but only the correction task was expected to stress working memory. The results were consistent with this hypothesis. Although performance in both tasks was significantly affected by syntactic variables, only in the correction task was performance associated with reading ability or affected by memory manipulations. Thus, syntactic knowledge was associated with reading disability only when its expression involved heavy memory demands, verbal response requirements and manipulation of sentential elements. (See Bentin, Deutsch, & Liberman, 1990, for a replication of these results with a similar population).

One must ask at what point a child's difficulties with a phoneme awareness measure may be wholly accounted for by the heavy and multiple phonological processing demands imposed by the task. Inasmuch as one can free phonological analysis tasks from extraneous memory and production requirements, will the reading disabled child continue to display a deficit in phoneme awareness? Again, for the purpose of the present study, the goal was to design a phoneme awareness task that would ask the child to isolate or identify phoneme segments, but that would not require manipulation or a verbal resonse.

Spelling strategies in phoneme awareness. A third interpretative concern relates to the hypothesis that successful performance on phoneme awareness tasks may result from rather than predict success in acquiring written language (Ehri, 1989; Morais, Alegria, & Content, 1987). Although prediction studies finding an association of early phonological awareness and later reading skill render a strong version of this hypothesis unlikely (e.g., Bradley & Bryant, 1983; Mann & Liberman, 1984; Perfetti, Beck, Bell, & Hughes, 1987; Share, Jorm, Maclean, & Matthews, 1984), it is a critical concern when examining the continuing association between reading disability and phonological awareness. Consider, for example, a study finding that adult readers have a considerable advantage over non-readers when asked to "say *pat* backwards" (Byrne & Ledez, 1983). As argued by Tunmer (1989), this task is handled most efficiently by using an orthographic strategy; non-readers without access to letter representations would be at a considerable disadvantage. Similarly, when a child is asked to "say please without the /l/" (Rosner & Simon, 1971), children who can read should be more inclined to work with the more tangible units of spelling wherever possible.

That subjects do indeed employ spelling strategies, where available, is demonstrated in several studies by Ehri and her colleagues. For example, when asked to count the number of sounds in *rich* and *pitch*, fourth graders report pitch to have one more segment (Ehri & Wilce, 1980). Similarly, invented spellings of young children indicate that post-vocalic nasals (e.g. ***bump, think***) are considered a part of the vo vel until spelling conventions indicate otherwise (Ehri, 1984).

Consequently, the advantage of the better readers on many phonological awareness tasks may derive from their ability to read or spell, rather than from an independent skill underlying reading, spelling and phonological awareness. Thus, it is important to have a phonological awareness measure that controls for spelling knowledge.

PURPOSE

The present study was designed to test the hypothesis that phonological awareness continues to be specifically and significantly associated with reading ability beyond the early stages of instruction. A new task was developed to measure phonological awareness which, paired with a nonverbal control task, would assess and control for the contribution of metacognitive ability and spelling strategies, while minimizing memory demands. To determine whether general metacognitive abilities contribute to individual differences in reading and phonological awareness, a phonological analog was created to parallel an existing measure of visual analytic ability, the Embedded Figures Test (EFT, Satz, Taylor, Friel, & Fletcher, 1978).[1] In the Embedded Figures Test, subjects are asked to identify which of three complex designs contains a specified shape. The parallel phonogical measure created for this study, the Embedded Phonemes Test (EPT), required subjects to identify which of three words, indicated both by pictures and oral presentation, contains a specified phoneme. To address further concerns that many tasks ostensibly measuring phoneme awareness make multiple demands on phonological processing, this task was designed to minimize extraneous requirements. No manipulation of segments was involved and the use of pictures reduced memory load and eliminated the need of a verbal response. The final consideration in designing the phoneme awareness task concerned the suggestion that superior performance on phoneme awareness tasks is a result of orthographic strategies, rather than consideration of the phonological representation. To assess this possibility, we compared performance on items in which consideration of the word's spelling would aid in identifying the embedded phoneme with peformance on those items in which knowledge of the word's spelling would not be of assistance.

This pair of measures was given to 48 second to fourth grade children, along with measures of word recognition, nonsense word reading and receptive vocabulary (Peabody Picture Vocabulary Test-Revised, PPVT-R, Dunn & Dunn, 1981). Subjects were required to have standard scores above 80 on the PPVT-R and were selected to vary widely in reading ability. Although all 48 subjects received the same battery of measures, different analyses on distinct subsets of the larger subject pool focussed on separate issues. For purposes of exposition, these different treatments are introduced as separate experiments below.

EXPERIMENT 1

The first experiment focussed on the contribution of phoneme awareness skills and general metacognitive skills to reading ability in ten pairs of school-aged children selected from the sample of 48 such that each pair was matched for age and vocabulary level, but differed on both reading measures. In this comparison, phoneme awareness, but not metacognitive skill, was predicted to be associated with reading. With regard to the spelling manipulation, it was predicted good readers would retain an advantage even when orthographic knowledge could not be invoked (Spelling Foil). However, consistent with Ehri (1989), the advantage was expected to be greater on those items in which spelling aids phoneme identification (Spelling Aid Condition). In short, this first analysis was expected to provide further, stronger, support to the large body of research suggesting that phoneme awareness is specifically associated with reading in schoolchildren.

Method

Subjects

To compare extreme reading groups matched on age and vocabulary score, ten pairs of more and less skilled readers were selected from the larger sample and individually matched on age and PPVT-R standard score. Reading group assignment required a consistent score on word recognition, word attack, and teacher evaluation. (See Table 1 for descriptive statistics).

Materials

Vocabulary. The *Peabody Picture Vocabulary Test-Revised* (Dunn & Dunn, 1981) was used to assess vocabulary; the subject selects which of four pictures corresponds to an orally presented label. The PPVT-R provides both a vocabulary age equivalent and a standard score which correlates highly with IQ scores on omnibus cognitive measures.

Table 1. *Characteristics of skilled and less skilled readers matched on age and vocabulary level.*

	Reader group			
	Less skilled readers (n=10)		More skilled readers (n=10)	
	M	SD	M	SD
(Age (years, months)	8,10	(0,8)	8,8	(0,8)
PPVT-R standard score	102.7	(10.4)	102.8	(9.8)
Word recognition (WJ13)				
raw score	28.5	(6.2)	36.7	(2.1)
standard score	102.6	(9.9)	122.4	(6.1)
grade equivalent	3.0		6.1	
Word attack (WJ14)				
raw score	7.8	(4.4)	19.4	(3.4)
standard score	94.6	(11.6)	118.2	(7.2)
grade equivalent	2.8		12.9	

Reading. The reading measures included two subtests from the *Woodcock-Johnson Psychoeducational Battery* (Woodcock & Johnson, 1977): a test of word recognition (WJ13: Letter-Word Identification), and a nonsense word decoding task (WJ14: Word Attack).

Non-linguistic analysis measure. The *Embedded Figures Test* (EFT) developed by Satz et al. (1978) was used to control for general metacognitive factors and other task variables common to phonological and non-verbal measures. The EFT measures the ability of the subject to recognize a simple component shape embedded within a more complex figure. As depicted in Figure 1, each target item is presented at the top of the page with three choices provided below in a row. Across all trials, the correct responses are evenly distributed among the three positions. The test includes 24 items graded in difficulty.

Experimental phonological awareness measure. The *Embedded Phoneme Test* (EPT) was developed to assess phonological awareness using a format parallel to the EFT. In the EPT, subjects were first presented with a familiar pictured item (*"Listen to the first sound in the word MAIL"*) and were then asked to pick which of the three words pictured below had that sound embedded within it (e.g., *Can you hear that sound anywhere in the word SWIMMING, in the word SNOWING, or in the word SWINGING*). (See Figure 2).

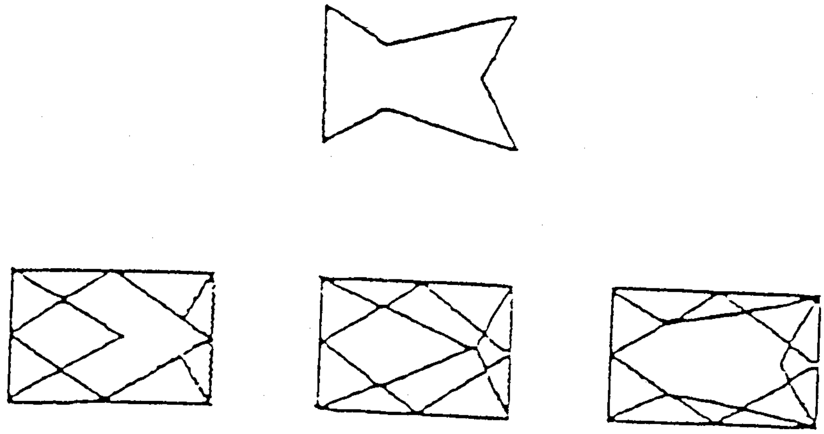

Figure 1. Sample item from the Embedded Figures Test.

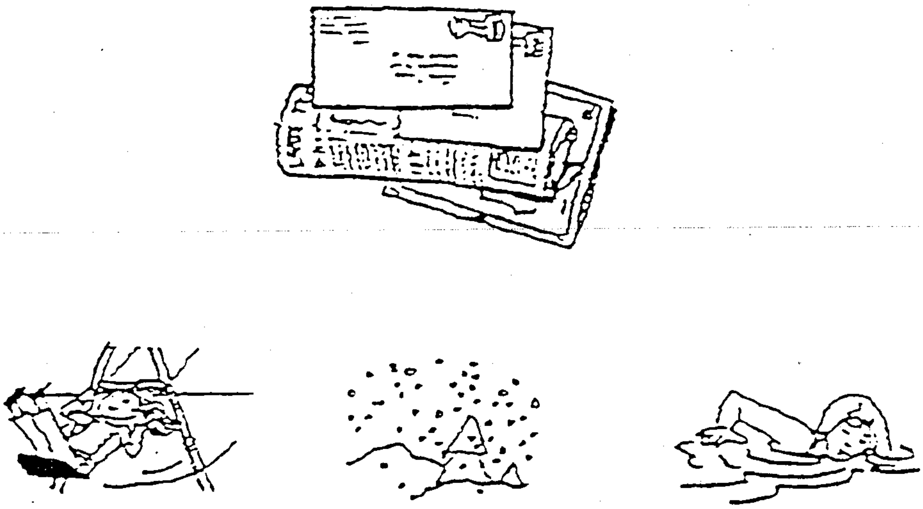

Figure 2. Sample item from the Embedded Phonemes Test.

The EPT was loosely modeled after a kindergarten measure requiring children to listen to a target word and to decide which of three words following had the same initial consonant (Stanovich, Cunningham, & Cramer, 1984a). In that study, kindergarten children performed at 73% correct on this task and performance was predictive of later reading skill. Although items from Stanovich (1984) were included for training and to establish a baseline measure of performance, the EPT measure differed from the earlier measure in two major respects. First, in the EPT, pictures accompanied the oral presentation. This served both to reduce memory demands and to parallel the non-verbal control. Secondly, in the EPT, the target segment was not always found in initial position but could occur anywhere within a word, serving to make the task more challenging for the school-aged child.

To directly assess the role of spelling strategies in performing this phoneme awareness task, two spelling conditions were included in addition to the three baseline items, for a total of 27 items. In approximately half of the cases (Spelling Aid Condition, 11 trials), consideration of the word's spelling would aid in identifying an embedded phoneme (e.g., *doll / bald-globe-block).* For the remaining items (Spelling Foil Condition, 13 trials), a spelling strategy alone could not lead to a correct response. In the Spelling Foil items the first letter of the target word either occurred in more than one of the choices (hence spelling was ambiguous, as in *ape / plant-pail-plaid*) or the first letter did not occur in any of the choices (it simply did not help, as in *zip / price-wasp-peas*)). In no case, however, was there a direct conflict between a spelling and sound response. (Refer to the Appendix for complete list of items).

The segments tested sampled evenly across stops, fricatives, nasal/liquids and vowels. These segments were embedded in monosyllabic (ape/pail), bisyllabic (mail/swimming) and multisyllabic (cat/skeleton) words. Target segments were assigned to either the first half or the latter half of the test word (leg/glass vs. chair/watch). Similarly, half the consonants were embedded in a cluster (run/astronaut); half were not (ship/dalmatian).

Distractors were selected such that each included at least one segment closely related to the target phoneme, differing from the target in only one feature. Thus, in the example shown in Figure 2, the [*n*] in *snowing* and the [*ng*] in *swinging* are phonetically similar to the target phoneme [*m*]. As in the EFT, all three choices were highly similar in overall configuration (e.g., number of syllables, morphemic structure). Further, to minimize erroneous strategies, the medial and final segments in the target item were consistently supplied or deleted in the three choices. Thus, in *zip/price-wasp-peas*, the final segment [p] of *zip* was present in all choices; the medial segment [I] was present in none of the choices. Words and pictures were carefully screened to avoid an association on the basis of semantic grouping (e.g. *fork /food* would not be acceptable).

In sum, the phonemes task was presented in a format nearly identical to that of the nonverbal figures task. In both, subjects were first shown a target picture (a geometric shape in the first case; a pictured object with a one-syllable label in the EPT). They were then asked to indicate by pointing which of the other three pictures contained the targeted shape or phoneme.

Procedure

All measures were administered to the subjects on an individual basis in two visits, each lasting 20-25 minutes. In the first, the vocabulary and reading measures were given following standard procedures. In the second, several weeks later, both the EFT and the EPT were presented, with order counterbalanced across children.

The metacognitive measures were introduced as "detective games." In the case of the EFT, they were told, *"Your job will be to find a shape hidden within a design. See this figure here? Can you find one just like it in any one of these figures?"* For the EPT, subjects were told, *"Now you are going to play another detective game, but this time, your job is to find sounds hidden in words."* Two items from Stanovich et al. (1984) kindergarten measure served to introduce the task. Feedback was provided on these items. (*"Listen to the first sound in the word FACE. Can you find that sound in the word PIG, in the word FORK, or in the word TOP?"*) Children were then tested on three similar items to determine a baseline level of phonological awareness. At this point, the experimenter introduced longer words, in which the target phoneme could be embedded anywhere. *"Listen to the first sound in FAN. Can you find that sound anywhere in the word CAMERA, DINOSAUR or BUTTERFLY?"* Subjects were explicitly encouraged to pay attention to the sounds of words rather than to their spelling and feedback was provided until the child understood the task. Although response latencies were recorded for both measures, they failed to play a significant role in performance on either task at this age level and are not entered in the analyses presented here.

Results

As can be seen in Table 2, mean performance on both the EPT and the EFT was well above chance level (33%).[2] Individual scores ranged from 44 to 96% correct in the Phonemes task; and from 50 to 95% correct on the Figures. Children performed almost perfectly (97% overall) on the baseline items drawn from Stanovich et al.'s (1984) kindergarten battery, indicating both that the children understood the task and could identify the initial phoneme. Thus, the difficult component of the EPT is in detecting the initial phoneme in one of the three choices.

Table 2. *Percentage correct on metacognitive measures as a function of reading ability.*

Metacognitive measures	Reading group: Less skilled readers (n=10)		More skilled readers (n=10)	
	M	SD	M	SD
Embedded Figures Test	75.8	10.4	78.8	10.7
Embedded Phonemes Test	57.0	7.7	69.6	15.1
Spelling Aid	57.3	8.6	71.8	22.0
Spelling Foil	46.9	13.8	60.0	18.1

Note: Overall score on the EPT is somewhat inflated due to inclusion of baseline measures; these are not included in the subtests.

As predicted, skilled readers performed significantly better than less skilled readers on the EPT, $t(18) = 2.35, p < .05$. In contrast, the two groups did not differ on the nonverbal analogue, the EFT, t (18) = 0.54, $p > .05$. The correlation between the two analysis measures was near zero, $r(20) = .01$, indicating that despite common task requirements, each is tapping quite a different ability. To determine the contribution of spelling strategies to subjects' performance, the percentage correct per reading group was calculated separately for the Spelling Aid and Spelling Foil conditions. In a repeated measures ANOVA, there was a significant effect of both reading group, $F(1,18) = 5.24$, $p < .05$, and spelling condition $F(1,18) = 7.06$, $p < 0.02$, with no interaction between them, $F(1,1) = .03$, $p > .85$.

Group differences were comparable in both the Spelling Foil and the Spelling Aid conditions; both were marginally significant in post-hoc Scheffe analyses, $F(1,18) = 3.3$ and 3.8, $p < .10$. Although the finding that both groups performed better in the Spelling Aid condition is consistent with Ehri (1989), spelling knowledge alone cannot account for the skilled reader's advantage on this phoneme awareness task.[3]

An even more rigorous test of the hypothesis that individual differences in phoneme awareness contribute to reading ability/experience involves the use of reading level controls (Bryant & Goswami, 1986). In such a design, older poor readers are matched to younger good readers on reading level and IQ; a continued deficit in phoneme awareness despite comparable reading levels, suggests that phonological awareness may play a causative role in reading ability. Just such a design was employed in the next set of analyses.

EXPERIMENT 2

This experiment was designed to address concerns that differences in performance on phoneme awareness tasks may derive from rather than contribute to a child's reading level. To this end, pairs of children were selected such that the poor readers were at least one year older and one year ahead in school than the younger good reader; the two groups were matched on reading level and PPVT-R standard score at the time of testing. Using this research method, it was predicted here that a deficit in phonological awareness as assessed here should continue to characterize the older poor reader (Bradley & Bryant, 1978). Poor readers were expected, however, to have an advantage on nonverbal tasks unrelated to reading as a function of their greater maturity and vocabulary age.

Method

Subjects

To compare good and poor readers when reading ability is matched, 16 pairs of older poor readers and younger good readers were individually matched on their both their word recognition raw scores and their PPVT-R standard scores (see Table 3 for descriptive statistics). To further emphasize differences in reading experience, the younger child in each pair was a grade or more behind the older child. In making these matches; where differences on the matching variables were observed between the two groups, it was the poor readers who were given the advantage.

Table 3. *Reading level comparisons.*

	Reading group		
	More skilled readers n=16 M (SD)	Less skilled readers n=16 M(SD)	T(30), p-value
Matching variables			
Word recognition - raw score	31.9 (4.7)	33.1 (3.9)	0.78, $p < .44$
Word attack - raw score	12.8 (5.1)	11.6 (4.2)	0.72, $p < .48$
Vocabulary - standard score	99.4 (10.6)	101.6 (13.4)	-0.51, $p < .61$
Distinguishing variables			
Age (years, months)	8.2 (0.4)	9.5 (0.5)	-9.59, $p < .0001$
Grade	2.4 (0.5)	3.5 (0.5)	-5.84, $p < .0001$
Word recognition - st'd score	116.8 (9.7)	104.5 (10.4)	3.46, $p < .002$
Word attack - st'd score	109.9 (8.6)	98.9 (9.5)	3.40, $p < .002$
Metacognitive tasks (percentage correct)			
Embedded Figures Test	75.4 (7.5)	72.5 (12.1)	0.73, $p < .47$
Embedded Phonemes Test	63.3 (10.7)	53.3 (5.9)	3.30, $p < .002$
Spelling Aid	65.3 (15.6)	55.7 (11.4)	1.99, $p < .06$
Spelling Foil	52.9 (16.6)	42.8 (8.4)	2.17, $p < .04$

Results

Despite significant advantages in chronological age, vocabulary age, years of schooling, and current grade level; and equivalent or higher scores on word recognition, older poor readers performed significantly more poorly than younger good readers in locating phonemes embedded in words $t\ (30) = 3.31, p < .003$. This suggests that individual differences in phoneme awareness play a causal role in determining reading ability. Contrary to expectations, but further strengthening the specific nature of the phoneme awareness deficit, the EFT failed to differentiate the two groups $t\ (30) = 0.73, p < .47$. A breakdown of scores according to spelling condition indicates that the significant difference on the EPT was upheld in both the Spelling Aid and the Spelling Foil condition, though the good readers had the greater advantage when spelling could not be brought to bear.

One might argue that the greater phoneme awareness of the good readers in this sample is directly related to their nonsignificant advantage on the nonword decoding test. To assess this possibility, a further comparison was made including only the 11 pairs of subjects in which the older poor reader was equal to or better than the younger good reader on the reading levels achieved on both word recognition and word attack subtests. Even under these more stringent conditions, the good readers maintained their overall EPT advantage (young $M = 17.1, SD = 2.8$; older $M = 14.3, SD = 1.5$), $t\ (20) = 2.97, p < .01$). They also maintained their advantage in the Spelling Foil condition (young $M = .53, SD = .14$; older $M = .41, SD = .08$), $t\ (20) = 2.52, p < .03$. Where spelling could provide assistance, however, it appears that the older poor readers capitalized on the knowledge they had acquired; this is reflected in the failure to find a difference between the two groups in the Spelling Aid condition (younger $M = .64, SD = .14$; older $M = .57, SD = .12$), $t\ (20) = 1.30, p < .20$.

To summarize, the analyses presented thus far indicate that subjects who are unequivocally "skilled" at both decoding and word recognition possess greater phoneme awareness than do subjects who are unequivocally "less skilled" on these same measures, largely independent of age, vocabulary knowledge and grade. This holds true even when both groups have attained comparable word recognition reading levels. However, the results also hint that progress in word recognition may proceed somewhat independently of both phoneme awareness and word attack skills. This hint is followed up in subsequent analyses involving a larger sample, including "average" readers whose performance is more variable and whose difficulties and strengths are not necessarily specific to reading. Using multiple regression analyses, it becomes possible both to replicate the specific association between reading and phoneme awareness observed in the previous analyses as well as to more analytically assess the association between phoneme awareness and each of the reading measures.

EXPERIMENT 3

In the current set of analyses, the association between phoneme awareness and reading ability was examined in the entire set of 48 subjects, selected to vary broadly in age, vocabulary level and reading ability. In an effort to extend the prior finding of a specific association between phoneme awareness and reading ability to a more heterogeneous sample, multiple regression analyses were employed to control for the possible contributions of age, vocabulary, and metacognitive ability as assessed by the EFT. Of particular interest was the opportunity to separately assess the association between phoneme awareness and the two reading measures (word recognition and word attack), once these other variables had been controlled for; the inclusion of "average" readers enhanced the possibility of greater dissociation.

In this sample of readers, simple correlations were expected to reveal associations between reading and all other variables, and between EPT and EFT. Once these associations were controlled for, it was predicted that EPT performance would continue to correspond with both reading measures. It was further predicted that word attack would explain further variance in performance on the EPT, even after controlling for differences in word recognition knowledge and the other variables.

Subjects

The subjects included 48 second, third and fourth graders between the ages of 7 1/2 and 10 years. Children were excluded if they obtained a standard score below 80 on the Peabody Picture Vocabulary Test-Revised (PPVT-R, Dunn & Dunn, 1981); or if English was not the primary language spoken in the home.[4] To obtain a cross-section of children, care was taken to find an equal distribution of Low, Mid and High readers with a spread of vocabulary levels at two age groups; equal numbers of boys of girls were included in each of the categories. (Refer to Table 4 for subject description).

Table 4. *Characteristics of all subjects participating in the study.*

	Age and reading ability levels							
	YOUNGER			OLDER			TOTAL	
	Low	Mid	High	Low	Mid	High	*M*	*SD*
n	8	8	8	8	8	8		
Age in months	98.4	99.8	99.0	112.0	113.3	112.0	105.6	7.7
PPVT-R standard score	99.6	100.6	104.6	94.8	102.4	113.5	102.5	12.2
WJ13 raw score	22.8	32.8	36.0	30.8	34.1	38.3	32.4	5.5
standard score	98.3	116.4	124.6	98.8	107.5	120.5	111	12.3
WJ14 raw score	4.6	11.8	17.8	9.0	13.2	20.3	12.8	5.9
standard score	91.5	107.8	117.5	94.4	102.5	116.3	105	12.6

Results

The correlation coefficients presented in Table 5 highlight the different pattern of associations characterizing the two metacognitive measures. Whereas general metacognitive skill, as assessed by the EFT, was correlated only with PPVT-R, phoneme awareness was specifically correlated only with reading. While the specificity of the association between phoneme and reading is consistent with earlier analyses, in this case, the two reading measures were allowed to diverge in subject selection. Although the two reading measures were highly correlated with each other, it is clear that it is decoding that most crucially depends on phoneme awareness; EPT was not correlated with word recognition ability. The association between the reading measures and EPT was further explored in multiple regression analyses.

Table 5. *Intercorrelations among experimental and predictor variables.*

	(n=48)				
	PPVT	WJ13	WJ14	EPT	EFT
1. Age	-.08	.29*	.15	-.04	.06
2. PPVT-R standard score	--	.32*	.28*	.06	.27+
3. Word recognition-WJ13		--	.86**	.15	.17
4. Word attack-WJ14			--	.37**	.21
5. Embedded Phoneme Test				--	.22
6. Embedded Figures Test					--

*$p < .05$
**$p < .01$
+$p < .06$

First, to determine how the reading measures were related to EPT performance, a best subsets analysis was performed comparing all possible combinations of the five predictor variables (age, word recognition, word attack, PPVT-R, and EFT). The optimal model to explain performance on the EPT included both reading measures: $r^2 = .240$, $F_{2,45} = 7.10$, $p < .01$; the inclusion of all predictors explained no further variance ($r^2 = .26$, $F_{5,42} = 2.96$, $p < .05$). Although the best model for explaining EPT performance included both reading measures, the two measures exerted quite different effects. The word attack measure was the major predictor ($r = .37$, $p < .01$); entered first, it had a positive standard coefficient of 0.91. Somewhat surprising, however, is the fact that in this sample the word recognition measure, when entered into the model after decoding, makes a significant, but *negative* contribution to EPT performance (standard coefficient = -0.63). Closer inspection of individual performance patterns indicates that children whose word attack skills were low relative to their word recognition scores performed even less well on our phoneme test than children whose word attack abilities were consistent with their word recognition vocabulary; this effect was over and above the general effect of word recognition and may suggests differences in reading strategies.[5]

The strength of the association between phoneme awareness and decoding skill is further indicated in a multiple regression analysis involving word attack as the dependent variable. Although word recognition, vocabulary, EFT, and age together explain 75% of the variance in performance on the word attack measure, phoneme awareness contributes an additional 5%

of the variance after all these variables have been entered, $F(1,42) = 11.05, p < .01$.

These results suggest that individual differences in performance on phoneme awareness tasks exist apart from general intellectual and metacognitive factors, and cannot be readily explained away even by experience. Rather, even in children making apparent progress in acquiring a word recognition vocabulary, phoneme awareness remains crucial to the decoding of novel words.

EXPERIMENT 4

The goal of the final set of analyses was to determine whether conclusions drawn with these novel phoneme awareness measure could fairly be extended to phoneme awareness measures in general. At the same time, it is important to assess the validity of the the EPT by comparing it to a widely used test of phonological analysis of proven reliability and validity. Because the original intent of this study was to create a nonverbal analog of an existing phonological awareness measure, the first 23 subjects tested were also administered the *Lindamood Auditory Conceptualization Test* (LAC, Lindamood & Lindamood, 1971). This provides the opportunity to determine whether the new phonological awareness involve the same abilities as the more established measure, the LAC.

Because the LAC was not specifically designed to minimize memory requirements, spelling strategies, or cognitive demands also involved in reading, it was predicted that the first order correlations between reading and the LAC would be greater than those between reading and EPT. For the same reason, it was predicted that performance on the LAC would correspond both to the PPVT-R score and EFT. On the other hand, it was also predicted that the two phoneme awareness measures, LAC and EPT, would be significantly correlated, despite the differences in task requirements (Stanovich et al., 1984). Consistent with the prior analyses involving the EPPT, it was predicted that the LAC would continue to correlate with reading performance even after controlling for PPVT and EFT.

Method

Subjects

Of the 48 children discussed in Experiment 3, a randomly selected subset (n = 23) were given both phonological measures. Descriptive measures on these children show them to be representative of the group as a whole (mean age 8 yrs. 9.1 mos., *SD* 8.0 mos.; PPVT-R mean 102.9, *SD* 13.6; WJ13 mean 32.7; *SD* 5.4, WJ13SS mean 110.5; *SD* 11.7, WJ14 mean 13.4; *SD* 6.1, WJ14SS mean 105.3; *SD* 13.4).

Materials

The materials are the same as in Experiments 1 through 3, but for the addition of the *Lindamood Auditory Conceptualization Test* (LAC, Lindamood & Lindamood, 1971), a widely used test of phonological analysis of proven reliability and validity. In this study, it was used for comparison with the EPT. In the LAC, the child is asked to manipulate colored blocks corresponding to the phonemic segments in nonsense words. Using this technique, the LAC measures the ability to isolate and compare sounds, and to discern their number and order within nonsense syllables. In the first part of the test, subjects are asked to place colored blocks in response to isolated speech sounds (e.g., to place two blocks of the same color to represent /z/ /z/, but to use two different colors to represent /z/ /m/). The second part of the test also requires the subject to represent sounds with colored blocks, but now syllables are introduced containing two to four segments. Items are presented in a pre-determined order such that only one change is required per item. For instance, the experimenter would present three different colored blocks and say, "this is /vop/, now show me /vops/." The next item would proceed from that: "this is /vops/, now show me /vups/." The score obtained is a combination of weighted raw scores from the two parts of the test. The maximum possible score is 100. The LAC correlates highly (.66 to .81) with combined reading and spelling scores on the Wide Range Achievement Test in children in grades K to 12 (Calfee, Lindamood & Lindamood, 1973); it was also highly significant in distinguishing good/poor reader groups in the third grade and in adult education classes (Pratt & Brady, 1988).

Procedure

The LAC was administered following standard procedures. It was presented in a separate 12 minute session within the same week as the PPVT-R and the reading tests.

Results

The group of subjects included in these analyses obtained scores on the EPT and EFT virtually identical to those achieved by the larger group from which they were drawn (see Experiment 3 for those statistics). The mean score on the LAC was 69.74 (SD 19.58), with a range in performance from 33 to 100. This score would place the children between the second and third grade, according to the LAC norms. Since the mean grade level of our subjects was 3.4, they were, on average, performing below grade level on this test. Correlations among vocabulary, reading, and analysis measures reveal associations similar to those observed in other subsets of subjects, but for an even higher overall correlation between EPT and the reading measures. PPVT-R and EFT continued to be nonsignificant correlates of EPT.Consistent with the findings of Calfee et al. (1973) and of Pratt & Brady (1988), the LAC scores of our sample also correlated significantly with reading measures, r_{23} = .47 to .57; $p < .05$. Also consistent with expectations, the LAC also correlated significantly with the EPT, $r_{23} = .53$; $p < .01$. (See Table 6 for correlations).

Table 6. *A comparison of two phoneme awareness measures.*

Correlations with reading, vocabulary, age and EFT (n=23)

Predictor variable	Phoneme awareness measure EPT	LAC
Word recognition	.42*	.47*
Word attack	.61**	.48*
PPVT-R standard score	.20	.61**
Age	.15	-.12
Embedded Figures Test	.39	.41+

+$p < .06$
* $p < .05$
** $p < .01$

The LAC diverged from the EPT in regard to their degree of association with the PPVT-R and the two reading measures. Stepwise regression analyses to predict LAC showed PPVT-R to be the most important predictor of LAC performance ($F_{1,21}$=12.33, $p < .05$) accounting for 37% of the variance. The second best predictor was the standard score on word Recognition; these two measures together accounted for 45% of the variance on the LAC ($F_{2,20}$= 9.13, $p < .01$). Age, EFT, and WJ14 explained no further significant variance. On the other hand, the EPT score, included after both PPVT-R and word recognition, further contributed an additional 12% of the variance on the LAC, the second phoneme awareness measure contributed ($F_{1,21} = 5.0$; $p < .05$). In sum, LAC peformance appears to depend heavily, though not solely, on general intellectual factors.

In contrast to the LAC performance, stepwise regression analyses to predict EPT performance in this subgroup, selected variables. Consistent with results reported for the entire group, the only significant predictor was word attack ($F_{1,21}$=12.20, $p < .05$, r^2=.37). EFT was a marginal predictor of EPT in this subgroup ($F_{1,21}$=4.05, $p = .06$), with WJ14 and EFT together explaining 45% of the variance ($F_{2,20}$=9.02, $p < .05$). Performance on the LAC did not contribute further explanatory power above and beyond that accounted for by the decoding measures. Non-significant predictors included word recognition, PPVT-R, age and sex.

In sum, although the EPT measure correlated fairly highly with the LAC, the two were by no means equivalent in how they related to decoding and word recognition. Whereas the EPT correlated best with a pure measure of word decoding (WJ14), the LAC correlated better with WJ13 - a standard measure of word recognition which taps experience, vocabulary and decoding skill. Whereas PPVT-R standard scores did not correlate significantly with EPT performance, it was the most significant predictor of performance on the LAC, suggesting that general intelligence and task demands appear to play an important role in performance on the LAC.[6]

GENERAL DISCUSSION

This study was directed at identifying and assessing the role of three factors that may account for the association between reading and phonological awareness once reading instruction has begun. To this end, a pair of measures was designed to simultaneously control for non-linguistic task demands and general analytic skill, while minimizing requirements of verbal production and working memory. In addition, the measures were designed to assess the contribution of reading experience and spelling strategies in explaining individual differences. Performance on this pair of measures by schoolchildren is consistent with and extends the findings of previous studies. The results indicate that reading ability, and particularly decoding skill, continues to be significantly associated with phonological awareness even when a number of other factors have been taken into account.

Metacognitive factors. First, the association between phonological awareness and reading ability appears to be largely independent of general metacognitive skill and non-linguistic task factors. Although phonological and nonlinguistic analysis tasks were presented in a nearly identical format, only the phonological measure successfully discriminated skilled from less skilled readers matched on age and vocabulary level. The lack of correlation between phonological awareness and and nonlinguistic awareness or between phonological awareness and general verbal ability suggests that a failure to understand and cope with extraneous task factors cannot explain poor performance on the EPT. Further support for the independence of phoneme awareness from general cognitive factors.

The present study goes beyond previous studies in also examining the pattern of abilities in a relatively unselected population of children whose reading profiles varied. Once again, the newly developed phonological awareness measure failed to correlate with general verbal ability or the nonlinguistic measure. Although this is not the case for all phonological awareness measures, as indicated in the comparison with the Lindamood task (LAC), the point to be drawn is that the relationship between phoneme awareness measures and reading does not simply derive from general cognitive factors.

The evidence that the particular nonlinguistic measure selected was useful as a pre-school predictor of reading success in other studies, but failed to correlate with reading in the present sample, is consistent with the suggestion that metacognitive factors may serve a catalytic, rather than an ongoing role in reading acquisition. In sharp contrast, the particular abilities required in phonological awareness tasks continue to be highly associated with reading well into the school years.

Extraneous memory demands. The second factor hypothesized to play a central role in explaining the association between phonological awareness and reading is working memory, defined broadly to include entering, maintaining, and retrieving items in a phonological store. In this study, such factors were not so much controlled for as minimized. Thus, the task did not require the subject to produce a verbal response or to reverse or manipulate phoneme segments. Further, the use of pictures allowed subjects to refresh their memory as needed under no time constraints, rather than requiring the subject to store and compare four different words in memory. With this format, each of the three alternative could be considered individually. That the phonological awareness task remained correlated with decoding skill rules out some of the less interesting explanations for the strong association between reading and phonological awareness; one need not artificially stress working memory, metacognitive factors or the production system to obtain an association.

On the other hand, it can not be concluded from these results that memory factors do not contribute to phonological awareness. Even in this simple task, the subject must maintain a segment in mind, and simultaneously scan one word at a time until a matching phoneme is encountered. Certainly, a dramatically impoverished verbal store will compromise performance even on this task (Dreyer, 1989). The present results instead serve to sharply restrict the potentially critical significance of working memory factors to their most intrinsic role in isolating and identifying individual phonemes at a single word level.

Reading experience and spelling strategies. The third factor, the role of reading level in affecting performance on phonological awareness measures, was addressed in two ways. First, although both skilled and less skilled readers were more accurate in their performance when spelling and phonological representations uniqely specify the same result (Spelling Aid), the continued advantage of skilled readers when spelling alone failed to provide cues makes it quite clear that it is not spelling alone that is conferring an advantage on the skilled readers. They can, at a better rate than the less skilled readers, go beyond their spelling knowledge to access and accurately select from among the phonological representations of the various choices presented. They are better able to isolate and identify the relevant sound units.

That phoneme awareness is not a simple function of reading and/or spelling expertise is further demonstrated by a comparison of older poor readers with younger good readers at equivalent reading-levels, where the poor readers had the advantage of age, vocabulary knowledge, and grade level. The finding that older poor readers lagged behind younger controls in both spelling conditions suggests that phoneme awareness continues to be an important determinant of reading aptitude during the school years.

Finally, the results of this study are consistent with the claim by Yopp (1988), that each phonological awareness measure brings its own task requirements. Although both of the phonological awareness measures compared here were associated with reading and with each other, they differed importantly in other respects. Whereas the LAC made heavy processing demands, the EPT appeared to be a measure of phonological awareness that is less confounded by general intelligence as assessed by a vocabulary measure. But even after controlling for these more general factors in the LAC, a word recognition measure explained an additional 10% of the variance in performance. The results of this study concur with others in showing that across very distinct phonological awareness measures, and after a number of task variables are controlled for, a core ability remains which is robustly associated with reading (Stanovich et al., 1984; Yopp, 1988).

In sum, this paper supports the view that phoneme awareness, specifically involving the isolation and identification of phonemic segments, is a continuing area of difficulty for schoolchildren with reading disability, deserving of our attention and concern.

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FOOTNOTES

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[1]We first attempted to use the *Lindamood Auditory Conceptualization Test* (LAC), with a musical control task (M-LAC), following Pratt (1984). Extensive work to adapt the M-LAC procedure to our needs was unsuccessful; Pratt's procedure paralleled only the first half of the LAC procedure and the lack of difference in her groups on this measure may have been due to ceiling effects. It was the lack of a suitable nonverbal control that motivated our move toward a new measure of phoneme awareness.

[2]Scores are presented in terms of percentage correct to facilitate comparison across different measures and conditions, which vary in the number of items included.

[3]In the current version of the EPT, the goal of the Spelling Foil condition was only to assess whether the advantage of the poor readers would be maintained when spelling crutches were absent. However, because the two conditions were not perfectly matched in all respects, the opposite conclusion cannot be drawn, that is, that the difference between performance on the Spelling Aid and Spelling Foil conditions derives from orthographic factors alone. This question is currently being investigated in a follow-up study in which an expanded version of the EPT includes a completely balanced design within the two spelling conditions.

[4]The pair of measures introduced in the present study were developed to be used as part of an extensive battery of language and nonlanguage measures in a large scale dyslexia subtyping study being conducted by Haskins Laboratories and Yale University Medical School. For future comparability with that study, subjects' ages and exclusionary criteria were determined by those established for the subtyping study.

[5]The independence of WJ13 and WJ14 is illustrated quite clearly among the eight children between 81/2 and 91/2 years of age who achieved "high" scores (37 to 40) on the WJ13 Word Identification Subtest. Four of these children made zero or one error on the WJ14 Word Attack test; these "decoders" achieved a score of between 74.1 and 96.3% correct on the EPT. The other four misread between four and ten items on WJ14; they scored between 44.4 and 66.7% correct on the EPT.

[6]These results differ from those of Pratt and Brady (1988) who report that vocabulary was not a significant factor in LAC performance among IQ-matched extreme reader groups in the second grade. Pratt and Brady (1988) did, however, find vocabulary to be associated with both reading and LAC performance in adults attending remedial education classes.

APPENDIX

EMBEDDED PHONEME TEST

Baseline items

PEAR	PEN	TILE	MASK
SOAP	KING	DIME	SALT
MILK	DATE	MOON	BAG

Monosyllabic

DOLL	BALD	GLOBE	BLOCK	*PAN	PHONE	SPONGE	SPHERE
CHAIR	BUSH	WATCH	DUST	*ZIP	PRICE	WASP	PEAS
LEG	GLASS	FROG	GRAPES	*WIG	WORM	WRITE	WRENCH
UP	KISS	MICE	BUS	*APE	PLANT	PAIL	PLAID

Bisyllabic

*TIE	CASTLE	FEATHER	PASTRY	*GAME	PIGEON	PICNIC	PENGUIN
*SOCK	TREASURE	WHISTLE	POISON	*JUICE	MEASURE	PICTURE	SOLDIER
MAIL	SWIMMING	SNOWING	SWINGING	*YOLK	MUSIC	LIQUID	NICKEL
AX	WINDOW	WAGON	WEDDING	*ICE	SUNSHINE	SANDWICH	SAILBOAT

Multisyllabic

BOX	VOLCANO	OCTOPUS	VEGETABLES	*CAT	SKELETON	SPAGHETTI	STRAWBERRY
VAN	UMBRELLA	ENVELOPE	GRANDFATHER	RUN	AMBULANCE	ASTRONAUT	ELEPHANT
NUTS	LAWNMOWER	HAMBURGER	FAMILY	*SHIP	GRASSHOPPER	EXPLOSION	DALMATIAN
INK	POCKETBOOK	BILLYGOAT	LAWNMOWER	*EAT	FISHINGROD	SPIDERWEB	JELLYFISH

*Spelling foil